DXFPreprocessing

ReadMe

```
In [ ]:   # DXF Preprocessing for CAD used to prepare electron-beam litho
          graphy files. Two seperate functionalities are included.
          # Both functionalities have in notebook plotting of the final D
          XFs for quality assurance.
          # Checking the CAD in an external program is recommend before f
          inally using for lithography.
          #
          # DXF Chip Builder
          # This code allows fast definition of a matrix of devices of th
          e same size from individual DXF files.
          # The user specifies which devices go where, and the number of
           rows and columns of devices.
          # Label handling and alignment mark placement are also implemen
          ted.
          # A template can be used instead of the alignment marks/labelin
          g where the script just drops in the devices in a row/column fo
          rmat of a user made DXF.
          # Note that unlike the INSERT object (aka MATRIX) in DXF which
           frustrates some lithography tools and can only replicate the s
          ame device,
          # here the user can specify any device at any position, and can
          keep a copy of the generating script as a record.
          # For integration with ElionixBatchExport Script, the user shou
          ld surround each device with a bounding box on its own layer (u
          sually called "matrix")
          #
          # Boolean Builder
          # Most CAD programs that support DXF, do not support Boolean op
          erations for the polyline class (which is used in all of lithog
          raphy).
          # All of the CAD programs that do Boolean operations for such o
          bjects, do not play well with DXF and create an import/export n
          ightmare.
          # This function is simple. With a simple python enviornment, yo
          u can take a DXF file, do any Boolean operation on any two laye
          rs,
          # and get a DXF with the output of that Boolean operation as a
           new layer (in a DXF named "outputFilename_c.dxf")
          # Support for multiple layer Boolean operations is planned, but
          not currently implemented.
```

Import

```
In [24]:  import os
          import sys
          import datetime
          import ezdxf
          import numpy as np
          from scipy.spatial import ConvexHull
          from itertools import repeat
          from ezdxf.addons import Importer
          import geopandas as gpd
          from shapely.geometry import Polygon, LineString
          import shapely
          import matplotlib as mpl
          import matplotlib.pyplot as plt
          %matplotlib notebook
          plt.style.use('dark_background')
```

DXFChip Builder

User Defined

```
In [2]: deviceDict = {}
        deviceDict.update({'11': 'HB_5um_1um_EBL_TG.dxf'})
        deviceDict.update({'12': 'HB_5um_1um_EBL_TG.dxf'})
        deviceDict.update({'13': 'HB_5um_1um_EBL_TG.dxf'})
        deviceDict.update({'21': 'HB_5um_1um_EBL_TG.dxf'})
        deviceDict.update({'22': 'HB_5um_1um_EBL_TG.dxf'})
        deviceDict.update({'23': 'HB_5um_1um_EBL_TG.dxf'})
        deviceDict.update({'31': 'HB_5um_1um_EBL_TG.dxf'})
        deviceDict.update({'32': 'HB_5um_1um_EBL_TG.dxf'})
        deviceDict.update({'33': 'HB_5um_1um_EBL_TG.dxf'})

        bottomLabel = 'Yacoby 24/05/2020 QC2749.11'
        topLabel = 'A.K.Saydjari'

        template_on = 0
        templateFileName = '3x3Template.dxf'
        outFileName = 'test.dxf'

        origin = [840, 840]
        device_size_x = 700
        device_size_y = device_size_x
        num_rows = 3                            #max is 9, if you are w
        riting more than 81 devices per chip, go to industry,
        num_cols = 3                            #collect more than $200
        and send it to aksaydjari@gmail.com
        letterSpace = 60 # um
        smallLetterSpace = 20 # um
```

```
In [3]: #Import Template (if applicable)
        if template_on == 1:
            doc = ezdxf.readfile(templateFileName)
        else:
            doc = ezdxf.new('R2018')
        modelspace = doc.modelspace()
```

```
In [4]: #Clean Up Empty Layers
        #layerList = list(doc.layers);
        #for layer in layerList:
        #    q = modelspace.query('*[layer=="{}"]'.format(layer.dxf.nam
        e))
        #    if len(list(q)) == 0:
        #        doc.layers.remove(layer.dxf.name)
```

Helper Functions

In [5]:
```python
# Add importfile to template modelspace witha shfit
def addShifted(finaldoc, finalmsp, importfilename, shiftListxy,
layerShiftInx):
    doc1 = ezdxf.readfile(importfilename)
    modelspace1 = doc1.modelspace()
    polyLineLayers = []
    polyLineColor = []
    polyLineVertices =[]
    lines = modelspace1.query('LWPOLYLINE')
    for idx, e in enumerate(lines):
        polyLineLayers.append('{}_{}'.format(e.dxf.layer,layerS
hiftInx))
        polyLineColor.append(doc1.layers.get(e.dxf.layer).color
)
        polyLineVertices.append([])
        for j, ver in enumerate(e.vertices()):
            polyLineVertices[idx].append(tuple(list((ver[0]+shi
ftListxy[0],ver[1]+shiftListxy[1]))))
        polyLineVertices[idx].append(polyLineVertices[idx][0])
    for indx, layer in enumerate(polyLineLayers):
        if layer not in finaldoc.layers:
            temp = finaldoc.layers.new(name=layer)
            temp.color = polyLineColor[indx]
        temp1 = finalmsp.add_lwpolyline(polyLineVertices[indx],
dxfattribs={'layer': layer})
        temp1.dxf.flags = 1
```

```
In [6]: lookupDictLarge=dict({
            'A':'a',
            'B':'b',
            'C':'c',
            'D':'d',
            'E':'e',
            'F':'f',
            'G':'g',
            'H':'h',
            'I':'i',
            'J':'j',
            'K':'k',
            'L':'l',
            'M':'m',
            'N':'n',
            'O':'o',
            'P':'p',
            'Q':'q',
            'R':'r',
            'S':'s',
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            'V':'v',
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            'c':'cc',
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            'e':'ee',
            'f':'ff',
            'g':'gg',
            'h':'hh',
            'i':'ii',
            'j':'jj',
            'k':'kk',
            'l':'ll',
            'm':'mm',
            'n':'nn',
            'o':'oo',
            'p':'pp',
            'q':'qq',
            'r':'rr',
            's':'ss',
            't':'tt',
            'u':'yy',
```

```python
        'v':'vv',
        'w':'ww',
        'x':'xx',
        'y':'yy',
        'z':'zz',
        '0':'0',
        '1':'1',
        '2':'2',
        '3':'3',
        '4':'4',
        '5':'5',
        '6':'6',
        '7':'7',
        '8':'8',
        '9':'9',

        '.':'period',
        '/':'forwardSlash',
})

lookupDictSmall=dict({
        '0':'00',
        '1':'11',
        '2':'22',
        '3':'33',
        '4':'44',
        '5':'55',
        '6':'66',
        '7':'77',
        '8':'88',
        '9':'99',
})
```

In [7]:
```python
# Add shift a letter to place
def addShiftedAlignmentPointBox(finalmsp, shiftListxy, align_la
yer):
    box = [(shiftListxy[0],shiftListxy[1]),(shiftListxy[0]+5,sh
iftListxy[1]),(shiftListxy[0]+5,shiftListxy[1]+5),(shiftListxy[
0],shiftListxy[1]+5),(shiftListxy[0],shiftListxy[1])]
    finalmsp.add_lwpolyline(box, dxfattribs={'layer': 'align_la
yer'})
def addShiftedLetter(finalmsp, string, shiftListxy):
    if string != ' ':
        for k in alphabet[lookupDictLarge[string]]:
            polyLineVertices = []
            for j, ver in enumerate(k):
                polyLineVertices.append(tuple(list((ver[0]+shif
tListxy[0],ver[1]+shiftListxy[1])))))
            finalmsp.add_lwpolyline(polyLineVertices, dxfattrib
s={'layer': 'label'})
def addShiftedMNumber(finalmsp, string, shiftListxy):
    if string != ' ':
        for k in alphabet[lookupDictSmall[string]]:
            polyLineVertices = []
            for j, ver in enumerate(k):
                polyLineVertices.append(tuple(list((ver[0]+shif
tListxy[0],ver[1]+shiftListxy[1])))))
            finalmsp.add_lwpolyline(polyLineVertices, dxfattrib
s={'layer': 'label'})
def addShiftedCoordObj(finalmsp, arrayObject, shiftListxy):
    for k in arrayObject:
        polyLineVertices = []
        for j, ver in enumerate(k):
            polyLineVertices.append(tuple(list((ver[0]+shiftLis
txy[0],ver[1]+shiftListxy[1])))))
        finalmsp.add_lwpolyline(polyLineVertices, dxfattribs={
'layer': 'label'})
def addShiftedCoordRotatedObj(finalmsp, arrayObject, shiftListx
y,angle):
    for k in arrayObject:
        polyLineVertices = []
        for j, ver in enumerate(k):
            rotated_coord = [ver[0]*np.cos(np.pi/180*angle)-ver
[1]*np.sin(np.pi/180*angle),ver[0]*np.sin(np.pi/180*angle)+ver[
1]*np.cos(np.pi/180*angle)]
            shifted_coord = [rotated_coord[0]+shiftListxy[0],ro
tated_coord[1]+shiftListxy[1]]
            polyLineVertices.append(tuple(list((shifted_coord[0
],shifted_coord[1])))))
        finalmsp.add_lwpolyline(polyLineVertices, dxfattribs={
'layer': 'label'})
```

```
In [8]:  ## Stored Alphabet
         #Lowercase is aa, uppercase is a, double numbers are a size sma
         ller for matrix indexing
         alphabet = {'aa': [[(30.269697815684594, 35.695595246422954),
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```

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```

```
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        (10.284915091860967, 16.633375329889503)]]}
```

```
In [9]: ## Stored Alignment Mark
        alignMark = [[(-5.000000247301386, -50.00000036277459),
          (-5.000000247301386, -5.000000362774471),
          (-2.473013865e-07, -5.000000362774471),
          (-2.473013865e-07, -10.0000003627747),
          (4.999999752698613, -10.0000003627747),
          (4.999999752698613, -50.00000036277459),
          (-5.000000247301386, -50.00000036277459)],
         [(-50.00000024730116, -5.000000362774471),
          (-50.00000024730116, 4.999999637225641),
          (-5.000000247301386, 4.999999637225641),
          (-5.000000247301386, -5.000000362774471),
          (-50.00000024730116, -5.000000362774471)],
         [(4.999999752698613, -5.000000362774471),
          (4.999999752698613, 4.999999637225641),
          (49.99999975269862, 4.999999637225641),
          (49.99999975269862, -5.000000362774471),
          (4.999999752698613, -5.000000362774471)],
         [(-5.000000247301386, 49.99999963722553),
          (-2.473013865e-07, 57.82499963722557),
          (4.999999752698613, 49.99999963722553),
          (-5.000000247301386, 49.99999963722553)],
         [(-2.473013865e-07, 9.99999963722587),
          (-5.000000247301386, 9.99999963722587),
          (-5.000000247301386, 49.99999963722553),
          (4.999999752698613, 49.99999963722553),
          (4.999999752698613, 4.999999637225641),
          (-2.473013865e-07, 4.999999637225641),
          (-2.473013865e-07, 9.99999963722587)],
         [(-5.000000247301386, -5.000000362774471),
          (-5.000000247301386, -3.627744718e-07),
          (-2.473013865e-07, -3.627744718e-07),
          (-2.473013865e-07, -5.000000362774471),
          (-5.000000247301386, -5.000000362774471)],
         [(-2.473013865e-07, -3.627744718e-07),
          (-2.473013865e-07, 4.999999637225641),
          (4.999999752698613, 4.999999637225641),
          (4.999999752698613, -3.627744718e-07),
          (-2.473013865e-07, -3.627744718e-07)]]
```

Main

In [10]:

```python
if template_on == 0:
    #Top Label
    x_insert = origin[0] + device_size_x*num_cols/2 - letterSpace*len(topLabel)/2
    y_insert = origin[1] + device_size_y*num_rows + letterSpace/2
    for idx, i in enumerate(topLabel):
        addShiftedLetter(modelspace, i, [x_insert+idx*letterSpace,y_insert])
    #Bottom Label
    x_insert = origin[0] + device_size_x*num_cols/2 - letterSpace*len(bottomLabel)/2
    y_insert = origin[1] - 2*letterSpace
    for idx, i in enumerate(bottomLabel):
        addShiftedLetter(modelspace, i, [x_insert+idx*letterSpace,y_insert])
    #Horz Matrix Label
    x_insert = origin[0] + smallLetterSpace
    y_insert = origin[1] - 2*smallLetterSpace
    for idx, i in enumerate(range(1,(num_cols+1))):
        addShiftedMNumber(modelspace, str(i), [x_insert+idx*device_size_y,y_insert])
    #Vert Matrix Label
    x_insert = origin[0] - 2*smallLetterSpace
    y_insert = origin[1] + smallLetterSpace - device_size_y
    for idx, i in enumerate(range(1,(num_cols+1))):
        addShiftedMNumber(modelspace, str(i), [x_insert,y_insert+(num_cols-idx)*device_size_y])

    ## Alignment Marks
    mark_sep = 400
    horz_offset = 70
    vert_offset = 80
    # Bot Marks
    addShiftedCoordObj(modelspace, alignMark, [origin[0],origin[1]-vert_offset])
    addShiftedAlignmentPointBox(modelspace,[origin[0],origin[1]-vert_offset],'global_align_1')

    addShiftedCoordObj(modelspace, alignMark, [origin[0]+device_size_x*num_cols,origin[1]-vert_offset])
    addShiftedAlignmentPointBox(modelspace,[origin[0]+device_size_x*num_cols,origin[1]-vert_offset],'global_align_1')
    # Top Marks
    addShiftedCoordRotatedObj(modelspace, alignMark, [origin[0],origin[1]+device_size_y*num_rows+vert_offset],180)
    addShiftedAlignmentPointBox(modelspace,[origin[0],origin[1]+device_size_y*num_rows+vert_offset],'global_align_1')
```

```python
        addShiftedCoordRotatedObj(modelspace, alignMark, [origin[0]
+mark_sep,origin[1]+device_size_y*num_rows+vert_offset],180)
        addShiftedAlignmentPointBox(modelspace,[origin[0]+mark_sep,
origin[1]+device_size_y*num_rows+vert_offset],'global_align_2')

        addShiftedCoordRotatedObj(modelspace, alignMark, [origin[0]
+device_size_x*num_cols-mark_sep,origin[1]+device_size_y*num_ro
ws+vert_offset],180)
        addShiftedAlignmentPointBox(modelspace,[origin[0]+device_si
ze_x*num_cols-mark_sep,origin[1]+device_size_y*num_rows+vert_of
fset],'global_align_2')

        addShiftedCoordRotatedObj(modelspace, alignMark, [origin[0]
+device_size_x*num_cols,origin[1]+device_size_y*num_rows+vert_o
ffset],180)
        addShiftedAlignmentPointBox(modelspace,[origin[0]+device_si
ze_x*num_cols,origin[1]+device_size_y*num_rows+vert_offset],'gl
obal_align_1')
        # Side Marks
        for idx, i in enumerate(range(1,device_size_y*num_rows//(2*
mark_sep)+1)):
            addShiftedCoordRotatedObj(modelspace, alignMark, [origi
n[0]-horz_offset,origin[1]+100+mark_sep*idx],-90)
            if idx == 0:
                addShiftedAlignmentPointBox(modelspace,[origin[0]-h
orz_offset,origin[1]+100+mark_sep*idx],'global_align_2')

            addShiftedCoordRotatedObj(modelspace, alignMark, [origi
n[0]-horz_offset,origin[1]-100+device_size_y*num_rows-mark_sep*
idx],-90)
            addShiftedCoordRotatedObj(modelspace, alignMark, [origi
n[0]+device_size_x*num_cols+horz_offset,origin[1]+100+mark_sep*
idx],90)
            if idx == 0:
                addShiftedAlignmentPointBox(modelspace,[origin[0]+d
evice_size_x*num_cols+horz_offset,origin[1]+100+mark_sep*idx],
'global_align_2')

            addShiftedCoordRotatedObj(modelspace, alignMark, [origi
n[0]+device_size_x*num_cols+horz_offset,origin[1]-100+device_si
ze_y*num_rows-mark_sep*idx],90)

        # Matrix Devices
        matrix_indices = [str(x+y) for x in range(10,(num_rows+1)*10,10
) for y in range(1,(num_cols+1))]
        for n in matrix_indices:
            bottomCorner = [origin[0]+device_size_x*(int(n[1])-1), orig
in[1]+device_size_x*(num_rows-int(n[0]))]
```
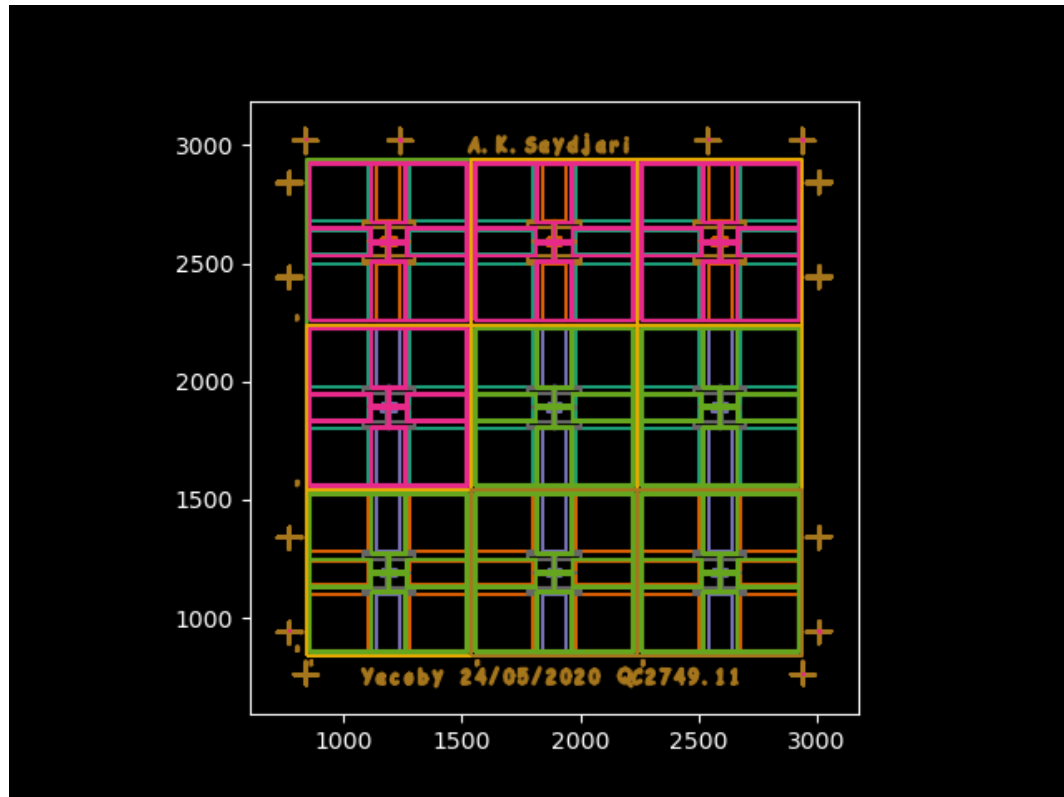
```
        addShifted(doc,modelspace,deviceDict[n],bottomCorner,n)
doc.saveas(outFileName)
```

In [29]:
```python
# Plotting
df = gpd.read_file(outFileName)
ax = df.plot(column='Layer', cmap='Dark2')
ax.set_facecolor((0, 0, 0))
```


Boolean Builder

User Defined

In [17]:
```python
inputFilename = 'BooleanTest.dxf'

layer1 = 'a'
layer2 = 'b'
targetLayer = 'c'
operation = 'AND'

outputFilename = '{}_bool.dxf'.format(os.path.splitext(inputFil
ename)[0])
```

Helper Functions

In [18]:

```python
def importDXFtoGPDwPolygons(fileName):
    df = gpd.read_file(fileName)
    df1 = df[df['SubClasses'] == 'AcDbEntity:AcDbPolyline']
    df2 = df1.copy()
    df2['geometry'] = df1['geometry'].apply(lambda x: Polygon(x
.coords))
    return df2
def exportGPDwPolygonstoDXF(df):
    df1 = df.copy()
    df1['geometry'] = df['geometry'].apply(lambda x: LineString
(x.exterior.coords))
    return df1
def relabelPostBoolGen(df,targetLayer):
    if 'Layer' in df.columns:
        df.loc[:,'Layer'] = targetLayer
        out = df
    else:
        dfb_out = df[df.isnull()['Layer_1']].copy()
        if not dfb_out.empty:
            dfb_out.loc[:,'Layer'] = targetLayer
            cols = dfb_out.columns.tolist()
            cols = cols[-1:] + cols[7:-2] + cols[-2:-1]
            dfb_out1 = dfb_out[cols]
            dfb_out2 = dfb_out1.rename(columns = {x: x.split(
'_')[0] for x in cols[1:-1]})
        else:
            dfb_out2 = gpd.GeoDataFrame([])

        dfa_out = df[df.notnull()['Layer_1']].copy()
        dfa_out.loc[:,'Layer'] = targetLayer
        cols = dfa_out.columns.tolist()
        cols = cols[-1:] + cols[1:6] + cols[-2:-1]
        dfa_out1 = dfa_out[cols]
        dfa_out2 = dfa_out1.rename(columns = {x: x.split('_')[0
] for x in cols[1:-1]})
        out = dfa_out2.append(dfb_out2)
    return out
def reMergePostBool(filename,boolOut):
    df = importDXFtoGPDwPolygons(filename)
    hexList = list(df['EntityHandle'])
    maxHex = max([int(x,16) for x in hexList])
    newHexlist = [format(x,'02X') for x in range(maxHex+1,maxHe
x+boolOut.shape[0]+1)]
    relabelBool = boolOut.assign(EntityHandle=newHexlist)
    return df.append(relabelBool)
def boolGeneric(filename,layer1,layer2, boolOp):
    df = importDXFtoGPDwPolygons(filename)
    dfa = df[df['Layer'] == layer1]
```

```python
        dfb = df[df['Layer'] == layer2]
        return gpd.GeoDataFrame(gpd.overlay(dfa, dfb, how=boolDict[
boolOp]))
def resaveWLayerColor(fileName, layerDict):
    doc = ezdxf.readfile(fileName)
    modelspace = doc.modelspace()
    for layer in doc.layers:
        if layer.dxf.name in layerDict:
            layer.color = layerDict[layer.dxf.name]
    doc.saveas('{}_c.dxf'.format(os.path.splitext(fileName)[0
]))
def getLayerDic(doc):
    layers = doc.layers
    return {lay.dxf.name: lay.color for lay in layers}
```

In [19]:
```python
boolDict = {
    'AND': 'intersection',
    'OR': 'union',
    'XOR': 'symmetric_difference',
    'MINUS': 'difference',
    'CUT': 'identity'
}
```
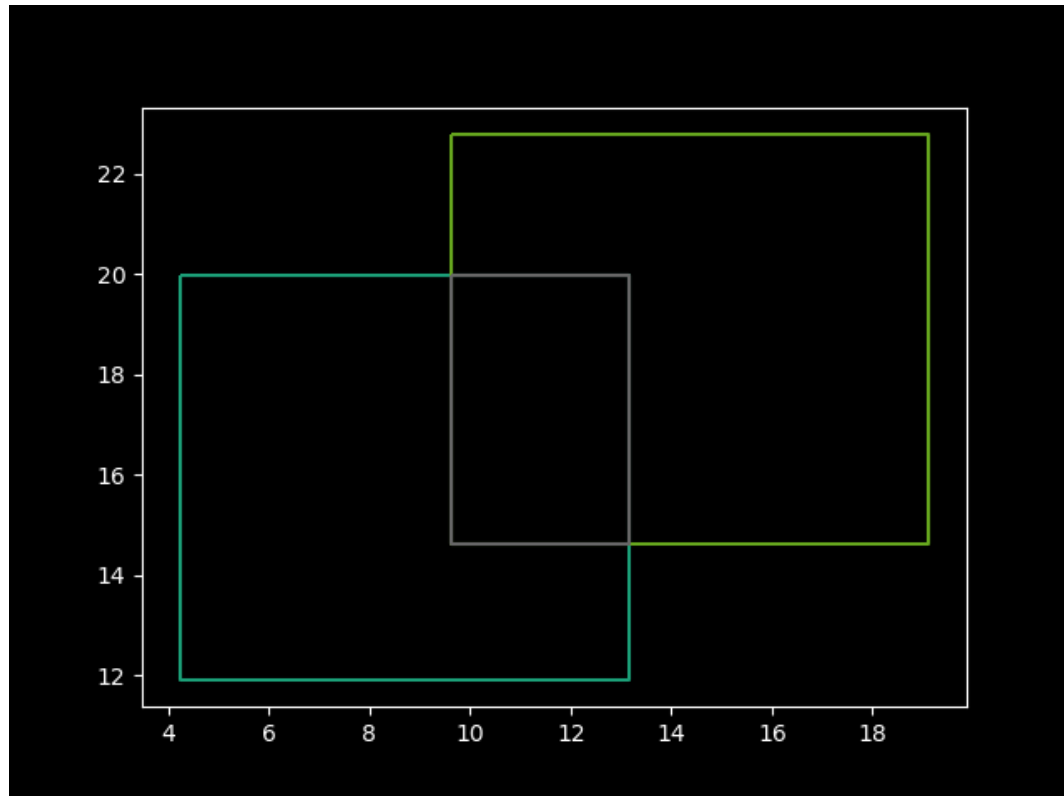
Main

In [20]:
```python
doc = ezdxf.readfile(inputFilename)
layerDict = getLayerDic(doc)
boolOut = boolGeneric(inputFilename,layer1,layer2,operation)
labelOut = relabelPostBoolGen(boolOut,targetLayer)
reMergeOut = reMergePostBool(inputFilename,labelOut)
exportGPDwPolygonstoDXF(reMergeOut).to_file(outputFilename, dri
ver='DXF')
resaveWLayerColor(outputFilename, layerDict)
```

In [30]:
```python
# Plotting
df = gpd.read_file('{}_c.dxf'.format(os.path.splitext(outputFil
ename)[0]))
ax = df.plot(column='Layer', cmap='Dark2')
ax.set_facecolor((0, 0, 0))
```


In [ ]: